NASA SensorWeb

SensorWeb 3G: Extending On-Orbit Sensor Capabilities to Enable Near Realtime User Configurability

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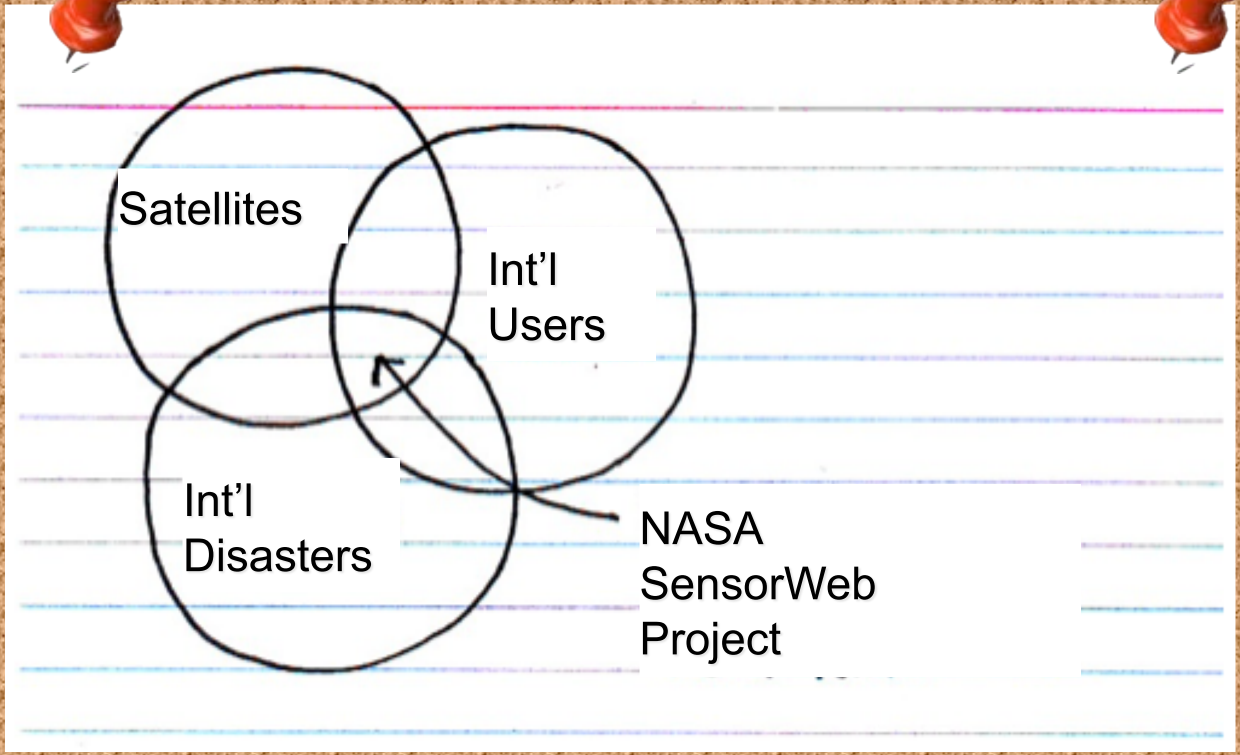
June 23, 2010

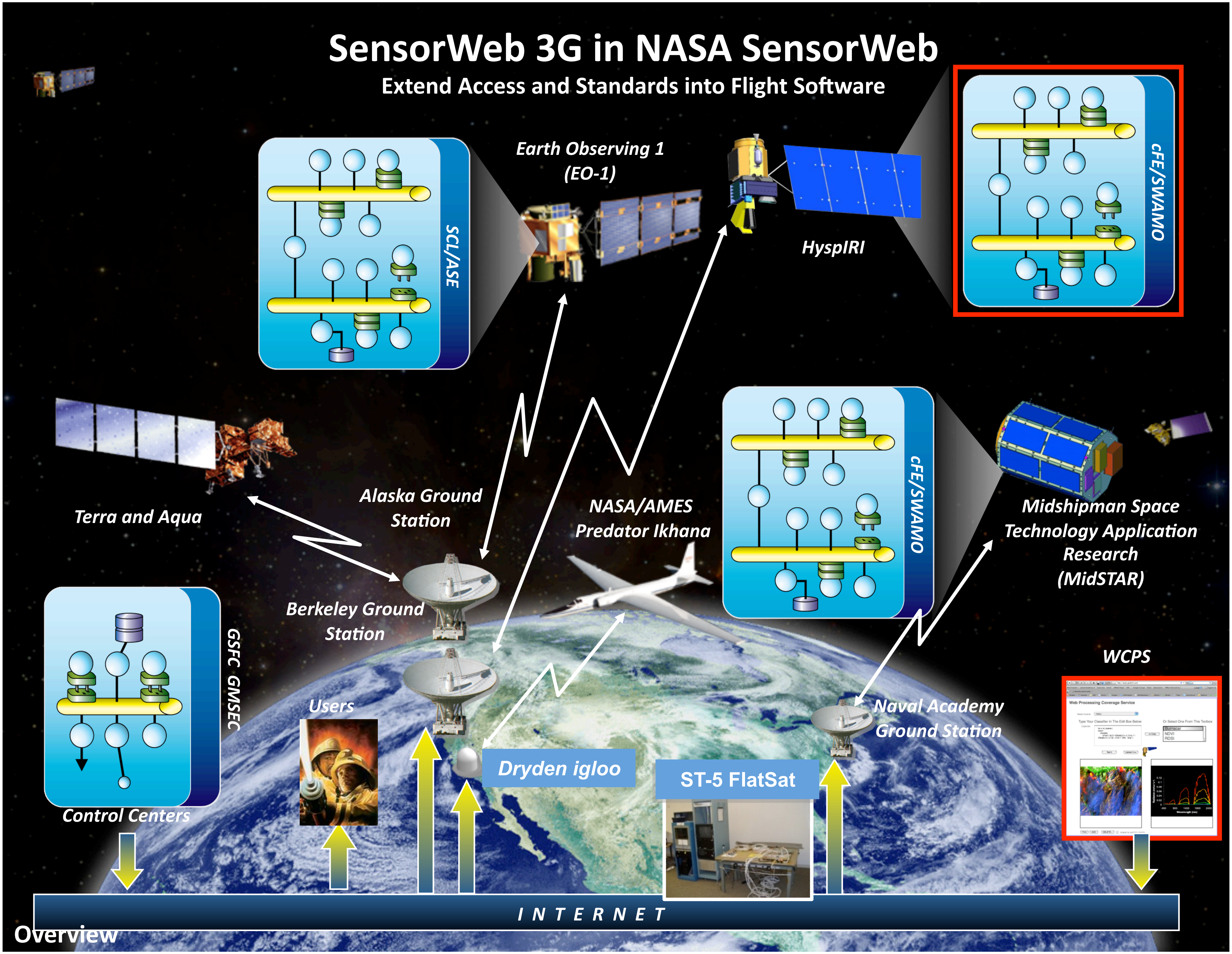
Presented at ESTF 2010

Sensor Web 3G

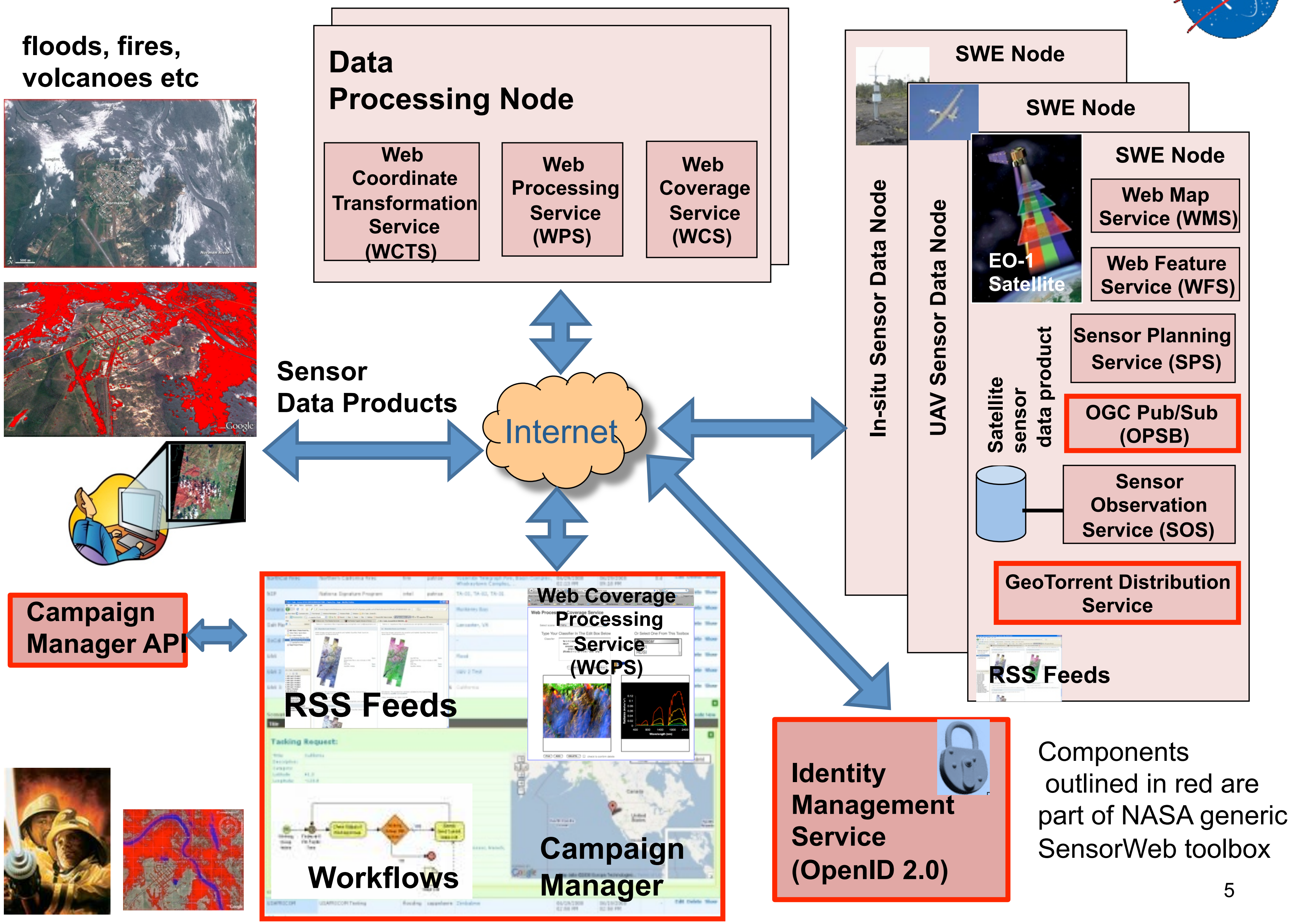

Satellites
Int'l
Users
Int'l
Disasters
NASA
SensorWeb
Project

General Approach for SensorWeb

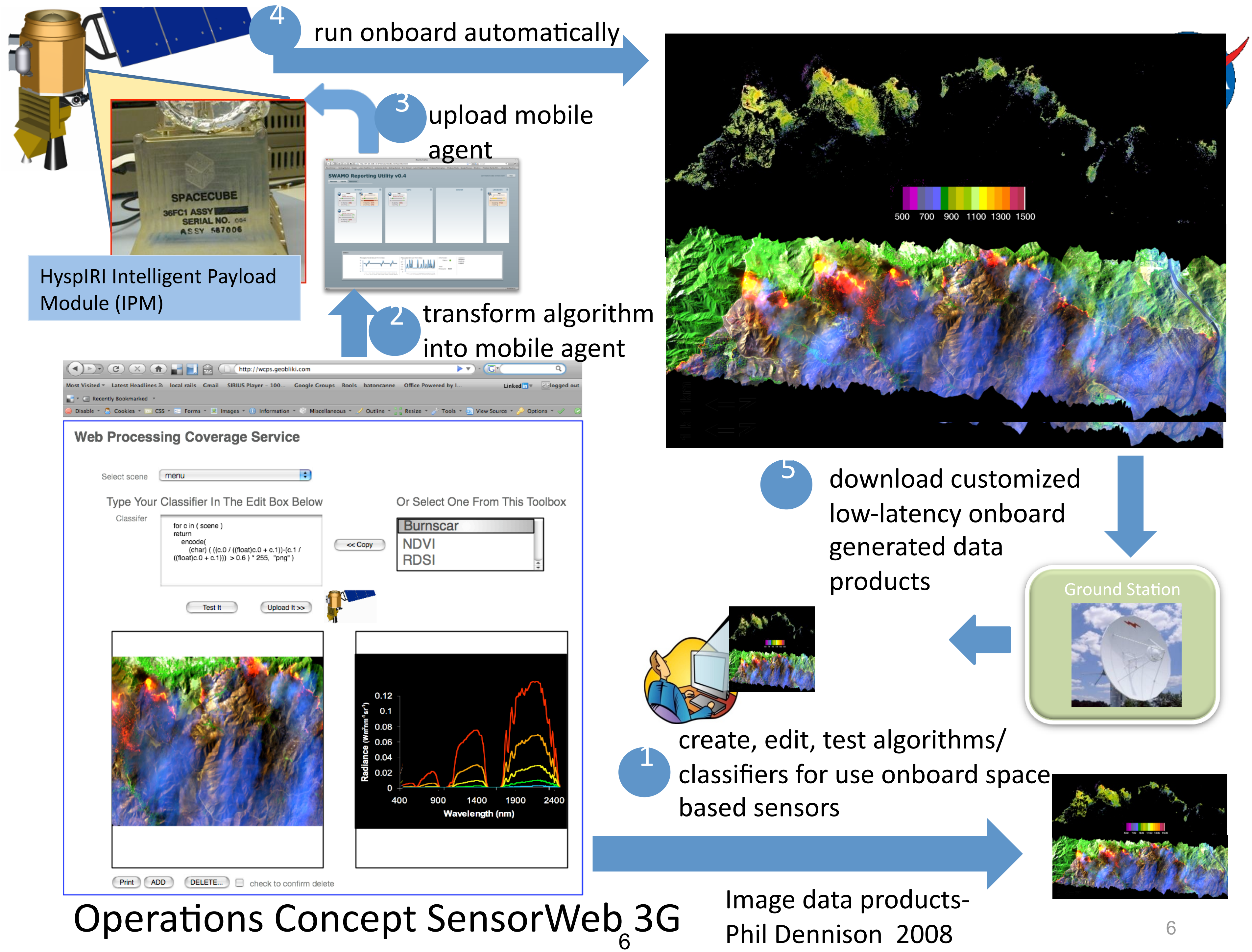
- Goal: Enable user to cost-effectively find and create customized data products to help manage disasters
  - On-demand
  - Low cost and non-specialized tools such as Google Earth and browsers
  - Access via open network but with required security (at minimum to NASA requirements)
- Use standards to interface various sensors and resultant data
  - Wrap sensors in Open Geospatial Consortium (OGC) standards
  - Wrap data processing algorithms and servers with OGC standards
  - Use standardized workflows to orchestrate and script the creation of these data products
- Target Web 2.0 mass market
  - Make it simple and easy to use
  - Leverage new capabilities and tools that are emerging
  - Improve speed and responsiveness


SensorWeb 3G in NASA SensorWeb
Extend Access and Standards into Flight Software
Earth Observing 1
(EO-1)
SCL/ASE
HyspIRI
cFE/SWAMO
Terra and Aqua
Alaska Ground
Station
NASA/AMES
Predator Ikhana
cFE/SWAMO
Midshipman Space
Technology Application
Research
(MidSTAR)
Berkeley Ground
Station
GSFC GMSEC
Users
Control Centers
Dryden igloo
ST-5 FlatSat
Naval Academy
Ground Station
WCPS
Web Processing Coverage Service
I N T E R N E T
Overview

SensorWeb High Level Architecture



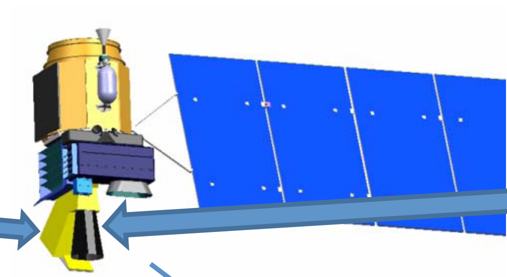
Components outlined in red are part of NASA generic SensorWeb toolbox



Operations Concept SensorWeb 3G

HyspIRI Use Case for SensorWeb 3G
HyspIRI Low Latency Data Product Concept

132 Mbps
Multispectral
Thermal InfraRed
(TIR) Scanner

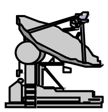


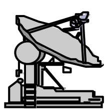
804 Mbps
Hyperspectral Visible
ShortWave InfraRed
(VSWIR) Imaging
Spectrometer

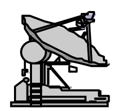
Spectral
Bands (8) 3.98 µm, 7.35 µm, 8.28 µm, 8.63 µm, 9.07 µm, 10.53 µm, 11.33 µm, 12.05
Spatial
IFOV 60 m
Range 600 km (±25.3° at 626 km)

Direct
Broadcast

Spectral
Range 380 to 2500 nm
10 nm bands
Spatial
Range ~146 km
(13.2 deg. at 626km)
Cross-Track Samples >2560
Sampling 60 m







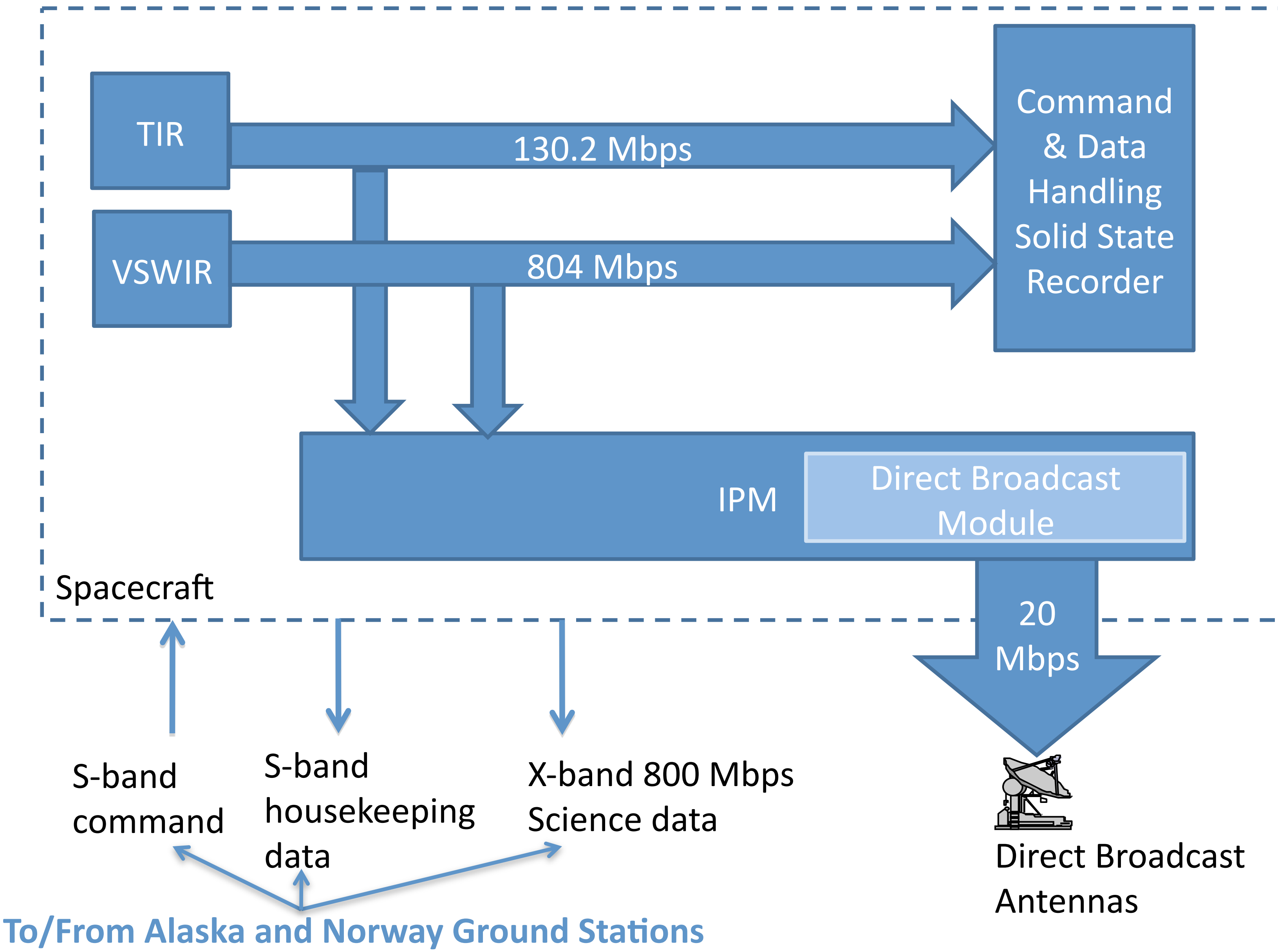
- 20 Mbps Direct Broadcast (10Mbps data throughput)
- Downlink Select Spectral Bands
- Select L-2 Products
- Continuous Earth-view Broadcast

HyspIRI IPM Highlights

2009 HyspIRI version of Intelligent Payload Module (IPM)
- Each instrument has microprocessor
- Add high performance computer as user driven intelligent processor

Functionality
- Real time receipt of VSWIR and TIRS data
- Direct Broadcast Downlink at 20 MBPS (10 Mbps throughput)
- Uploadable user developed classification algorithms via S-band
- Automated onboard workflows execute algorithms
- Onboard planner functionality to enable downlink of messages and data subsets via direct broadcast or S-band for rapid turnaround
- Onboard science data processing (i.e. cloud screening, thermal summary) other onboard data reduction functionality
- Related ground software to enable desktop data delivery, loadable classifiers
- Basic architecture, ground and flight software being developed under 2 ea 3 year ESTO awards (Mandl/GSFC, Flatley/GSFC)
- Based on already existing EO-1 Software, upgraded for HyspIRI flight computer

HyspIRI Data Flow



Low Fidelity HyspIRI IPM Testbed

NETGEAR Gigabit Switch

- Allows the board and the data generator workstation to connect at Gigabit speed.

Data Generator Workstation

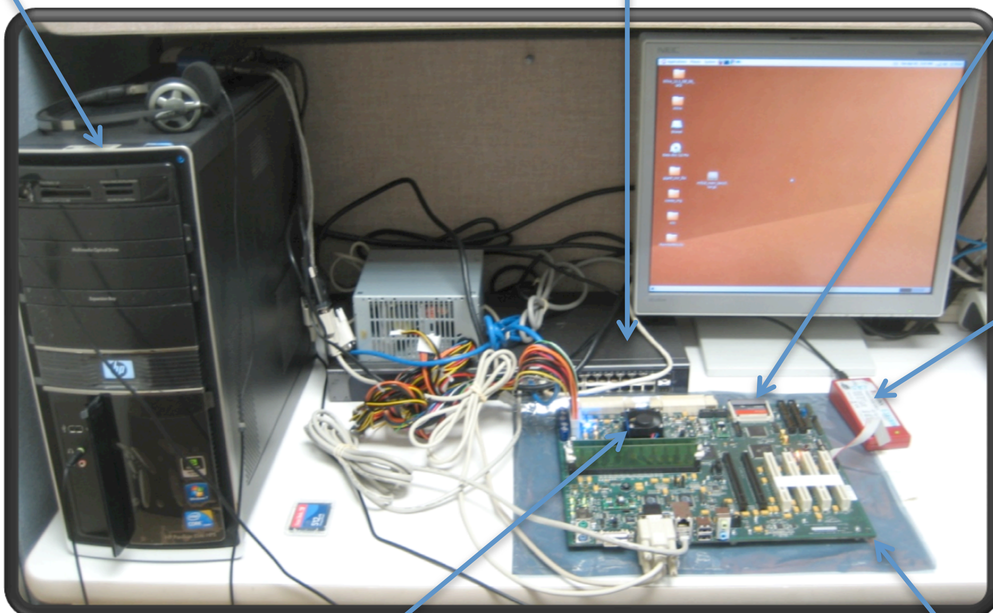
- Generates test data and streams it to the board at rate up to 800Mbps.

Compact Flash

- Ext3 formatted file system with Linux libraries and tools

Platform Cable USB

- Provides an easy method for debugging software running on the board



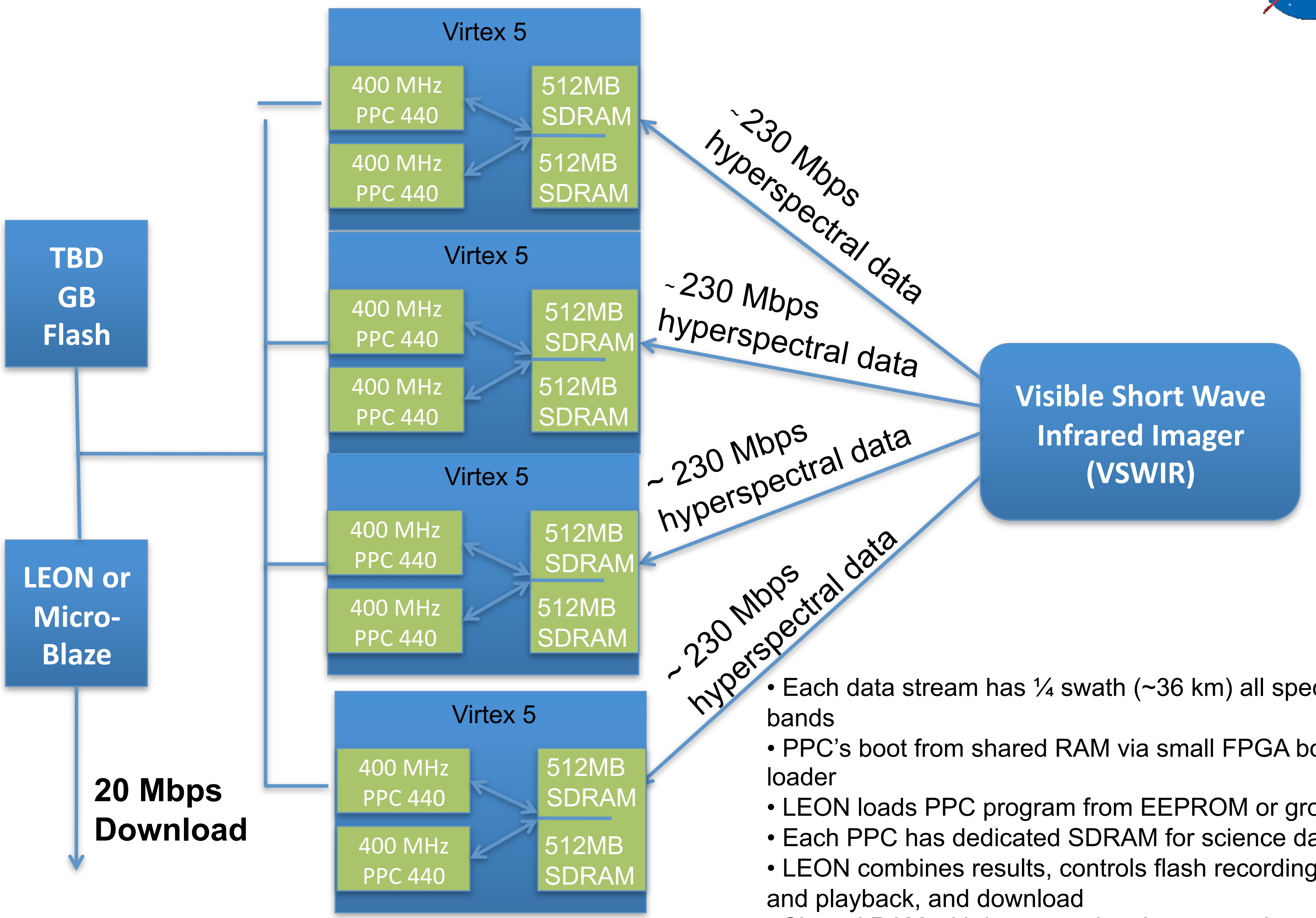
Virtex-5 FPGA

- GSFC Space Cube 2 core FPGA
- Configured as dual 400MHz PPC design
- Capable of running with Linux or in a standalone mode

Xilinx ML510 Development Board

- Enables the development team to verify the Virtex-5 while the GSFC Space Cube 2 is finalizing the design

HyspIRI VSWIR Data Processing Architecture Only



- Each data stream has ¼ swath (~36 km) all spectral bands
- PPC's boot from shared RAM via small FPGA boot loader
- LEON loads PPC program from EEPROM or ground
- Each PPC has dedicated SDRAM for science data
- LEON combines results, controls flash recording and playback, and download
- Shared RAM with interrupt signals to pass data PPCs <-> LEON

A Closer Look

TBD
GB Flash

LEON or MicroBlaze Control Processor

- **RTEMS OS**
- **cFE or dynamic software bus**
- **CFDP**
- **DTN**
- **CASPER / onboard planning**
- **Fault Monitoring, recovery software**
- **Flash / RAM file systems**
- **S/C command and telemetry software**
- **End-to-end command interface**
- **Direct broadcast downlink interface**
- **Data compression**
- **SWAMO**
- **Interface support: 533, SpaceWire, Gbit Ethernet**
- **Non-volatile storage support: PROM, EEPROM, Flash.**

Virtex 5

400 MHz PPC 440
- I/O Processor
- Band Stripping using FPGA logic

400 MHz PPC 440

- Data processing
- Corrections: geometric, radiometric, atmospheric
- Products: cloud cover, fire detection, vegetation composition, oil spills, algae blooms, etc.

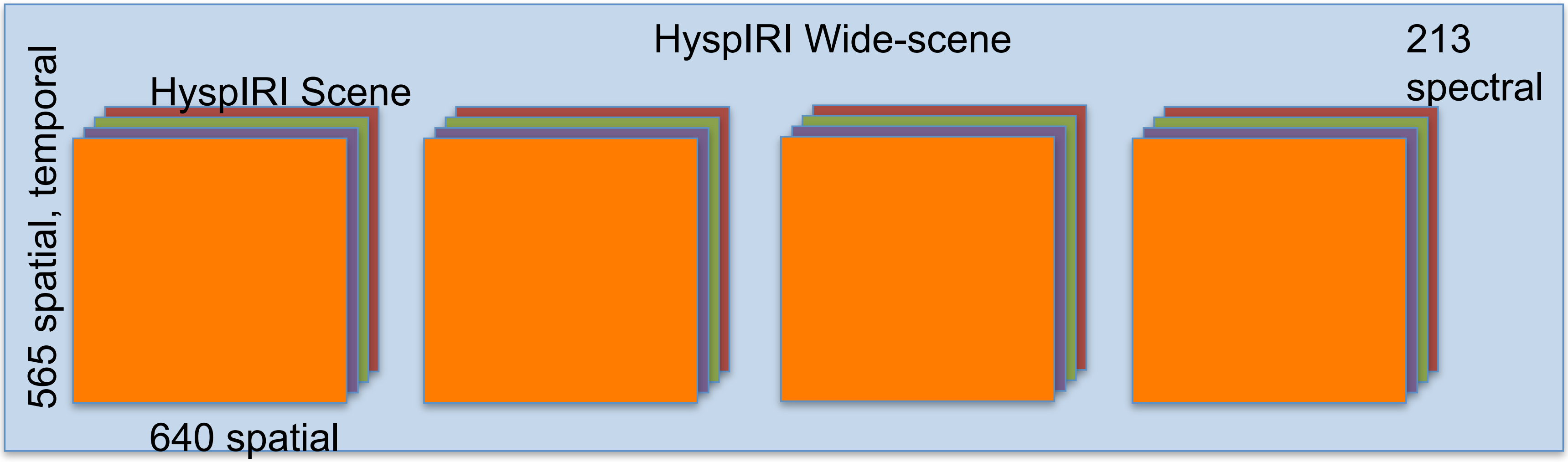
512MB SDRAM

Shared RAM

512MB SDRAM

HyspIRI IPM Hyperspectral Scene

- HyspIRI Scene at 5 second data take - 38 km x 34 km (640 pixels x 565 pixels)
- HyspIRI Wide-scene – consists of 4 HyspIRI Scenes
  - 153.6 km x 34 km (2560 pixels x 565 pixels)
- Flight software will process 4 HyspIRI Scenes in parallel
- Each band consists of 640 pixels of a single spectral range
- Each frame will consist of 213 bands
- Each scene will consist of 565 frames
- Each Power PC processor will ping pong HyspIRI scenes, processing one scene while the next is flowing into memory
- Each scene will require 308 MB memory
- Scenes will be stored in memory in band sequential order in an array of words



Initial Benchmark Results

32-bit Memory Test	Write (ms)	Read + Verify (ms)
128MB	711	1179
256MB	1564	2365
512MB	2942	4731
1024MB	6673	10670

Not Optimized!
FPGA not leveraged

Algorithms	Linux (ms)	Standalone (ms)	Linux (ms)	Standalone (ms)
	EO1 scene (256 x 1000 pixels)		HyspIRI ¼ swath (640 x 565 pixels)	
Cloud	1791	431	2170	589
Flood	3024	937	3782	1311
SWIL	7350	2872	10226	4058
Sulfur	116362	29515	164978	42026
Thermal	1103	304	1475	431
SIWI	580	44	823	62
NDVI	630	44	904	62
NDWI	589	44	836	62

Disclaimer: Code not optimized. Performance based on a 400MHz PPC design.

Vision for Development of IPM Process Chain

Processes	Ground	Flight
Level 0	Yes	-
Level 1R	Yes	-
Atmospheric Correction	Automation in progress	-
Dynamic Algorithms	JPL WCPS/SWAMO	In Testbed
Geometric Correction	L1G	-
Compression	CCSDS	Card Available
Downlink	N/A	-

WCPS Language Implementation

Language Primitives	Completion Status
Processing Expression	100%
Store Coverage Expression	100%
Encoded Coverage Expression	100% (added kmz)
Boolean Expression	100%
Scalar Expression	80%
Get Metadata Expression	-
Set Metadata Expression	-
Coverage Expression	100%
Coverage Identifier	100%
Induced Expression	100%
Unary Induced Expression	80%
Unary Arithmetic Expression	90%
Trigonometric Expression	-
Exponential Expression	-

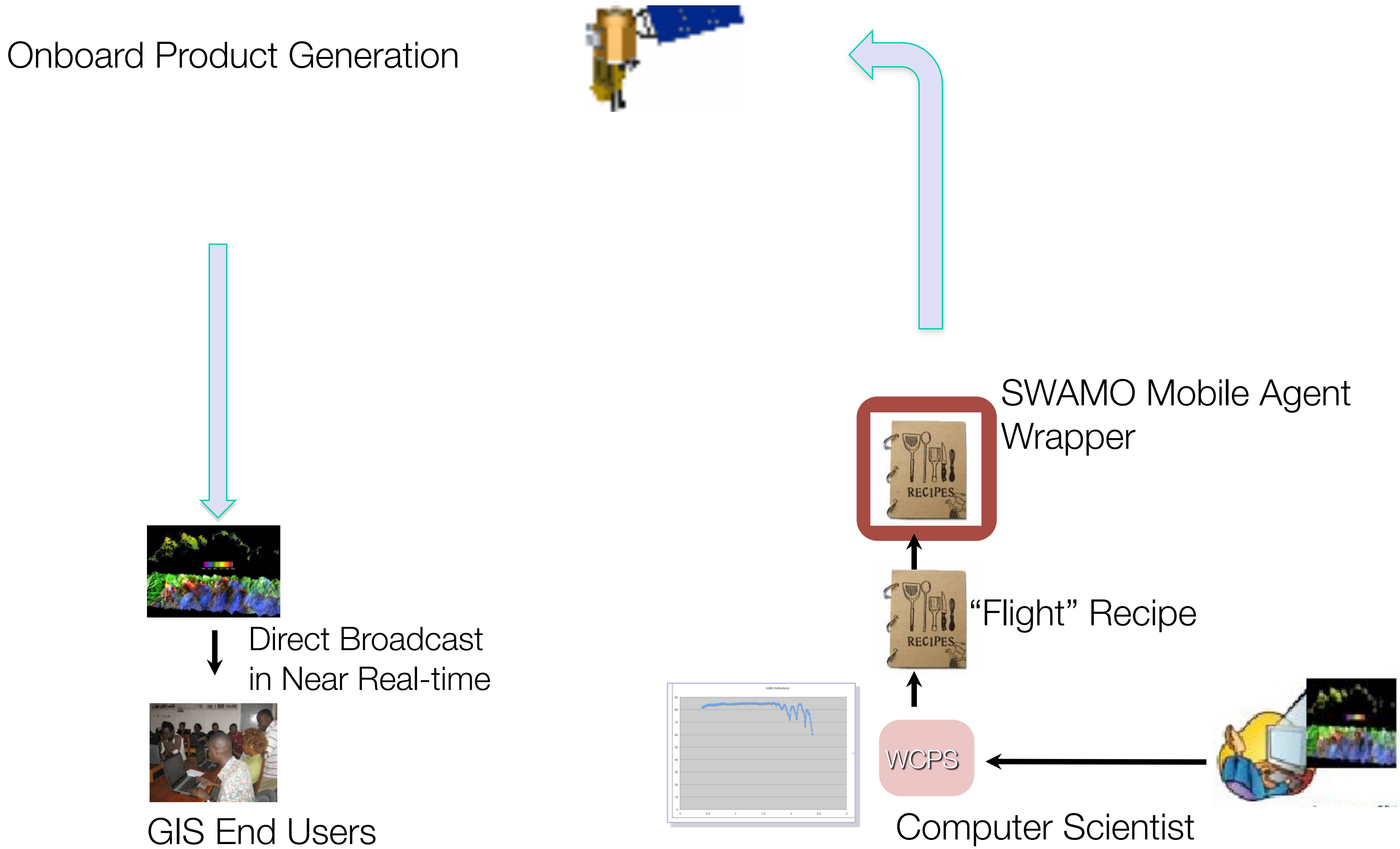
More Info: http://www.petascope.org

WCPS Language Implementation

Language Primitives	Completion Status
Boolean Expression	100%
Cast Expression	-
Field Expression	80%
Binary Induced Expression	80%
Range Constructor Expression	90%
Subset Expression	60%
Trim Expression	-
Extend Expression	-
Slice Expression	-
Scale Expression	-
CRS Transform Expression	-
Coverage Constructor Expression	60%
Condense Expression	30%
General Condense Expression	10%
Reduce Expression	10%

Potential Use Cases: Extending SensorWeb 3G to Detect Materials Onboard a Satellite

Specific Example of Possible of SensorWeb 3G with IPM

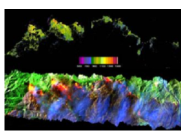


Specific Example of Possible of SensorWeb 3G with IPM

Reflectance Algorithms

Pattern Matching Algorithms

Geometric Correction Algorithms

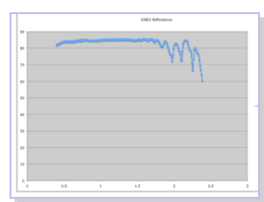


Direct Broadcast in Near Real-time

GIS End Users

SWAMO Mobile Agent Wrapper

“Flight” Recipe



WCPS

Computer Scientist

Use Case Experiment 1

NATO Seizes Tons of Bomb Material in Afghan Raid

Tuesday, November 10, 2009
Associated Press

Print | ShareThis

KABUL — International troops and Afghan police seized 250 tons of ammonium nitrate fertilizer — enough to make up to a couple hundred roadside bombs, the Taliban's most lethal weapon in what has been the deadliest year of the war, NATO announced Tuesday.

Separately, video footage emerged of insurgents brandishing what appears to be limited stocks of U.S. ammunition in a remote area of eastern Afghanistan where eight Americans died in a battle last month.

NATO officials hoped Sunday's raid in the southern city of Kandahar would hurt Taliban militants, whose homemade bombs have become the biggest killer of U.S. and allied troops.

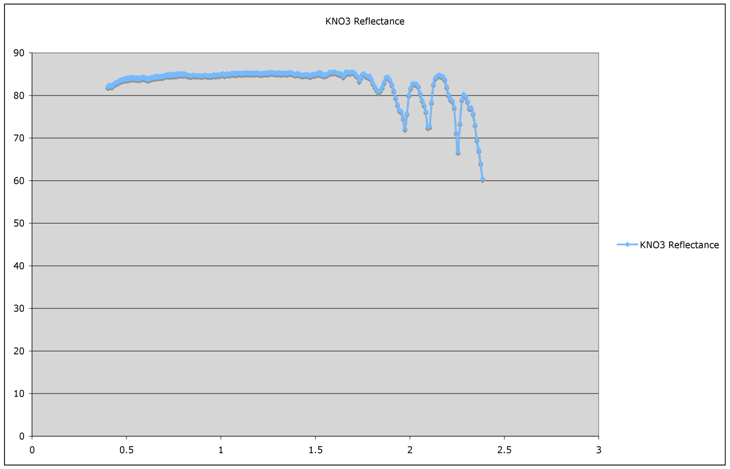
Acting on a tip, international forces and Afghan police discovered 1,000 100-pound bags of ammonium nitrate fertilizer and 5,000 parts for roadside bombs in a warehouse, the military said. After the initial find Sunday, an additional 4,000 100-bags of fertilizer were found in a nearby compound. The joint forces also made 15 arrests.

The seizure included enough fertilizer to make dozens to a couple of hundred roadside bombs, said John Pike, director of the military think tank Globalsecurity.org.

The insurgents have been successful manufacturing homemade bombs from materials such as fertilizer, which is easily available in agricultural areas of the south.

Experiment 1 with KNO3 Detection Using EO-1 Atacama Desert, Chile

- User uploads signature of interest to spacecraft
  - Example: Potassium Nitrate (KNO_3, Niter, saltpeter) (USGS Spectral Library) used in Fertilizer and Explosives. Major Source Can be Found in Atacama Desert, Chile.

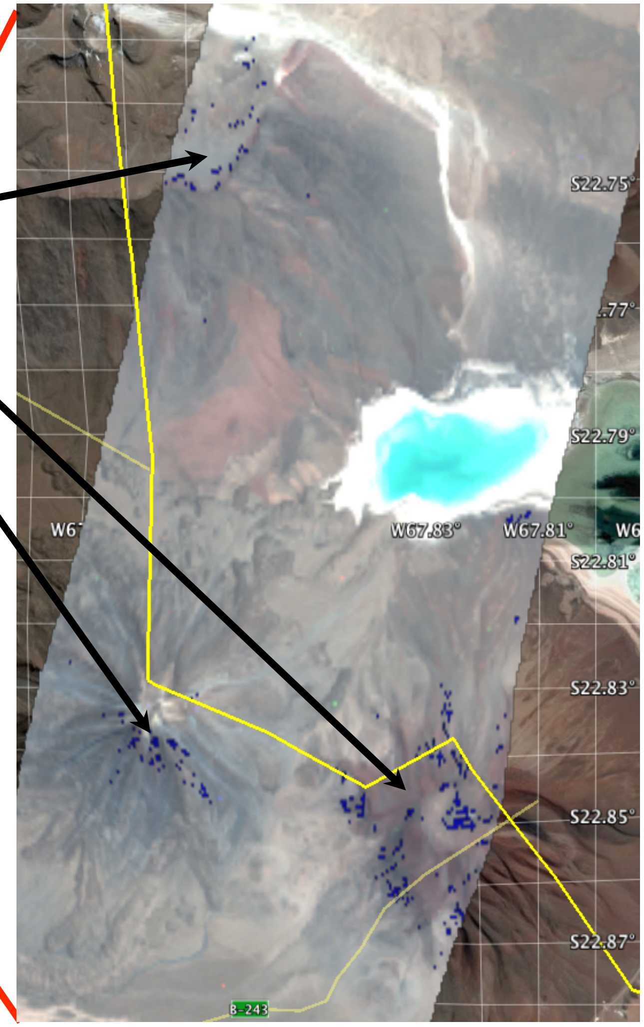


Experiment 1 with KNO3 Detection - Atacama Desert, Chile conducted with Earth Observing 1

Product Generated Onboard: 7KB (EO-1)
Original Raw Data: 2.7GB

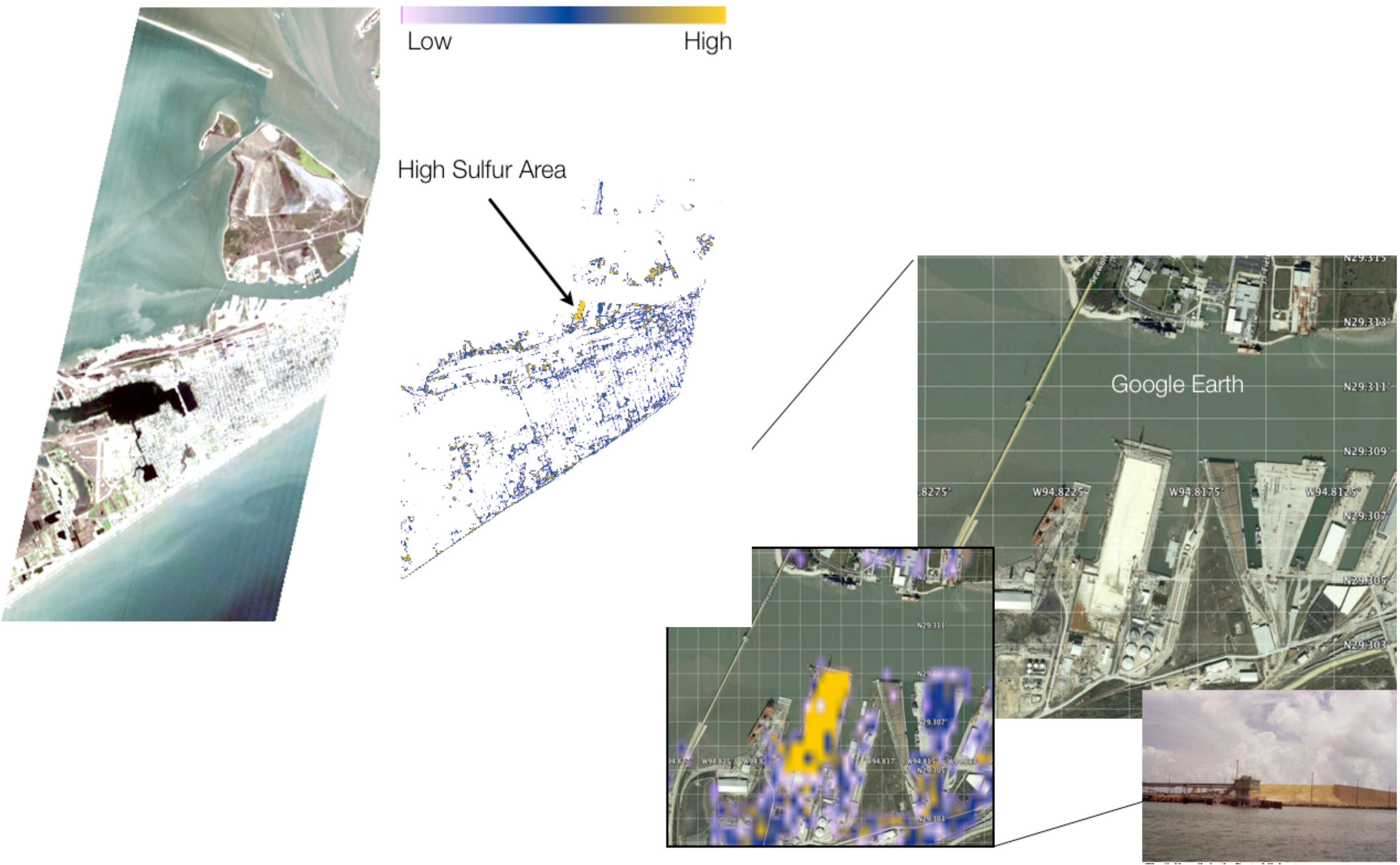
Potential KNO3

Detected Pixels (blue) as Overlay on Google Earth



In Less than 1 hour with a slow onboard CPU

Experiment 2 Detect Known Sulfur Pile Galveston Using EO-1



Global Hawk Infusion

- Coordinating ramp up to integrating WCPS-SWAMO-cFE onto Global Hawk
  - Test cFE on Global Hawk testbed spring 2010 (Don received cFE in Feb 2010)
  - Test WCPS-cFE-SWAMO on actual mission with target being GRIP mission in Fall 2010
  - Don Sullivan is main software architect for Global Hawk missions and therefore can authorize loading of cFE-SWAMO onto the Global Hawk
- Benefit
  - Access onboard SensorWeb planned for the atmospheric mission
  - Near real-time change of onboard instrument algorithms from ground

Conclusion

- Extending SensorWeb into the flight software domain increases the flexibility and power of the SensorWeb
- New onboard high speed computers provide new opportunities to integrate functions formerly constrained to ground
- Standard interfaces provide easier access to onboard resources, thus lowering the barrier to entry